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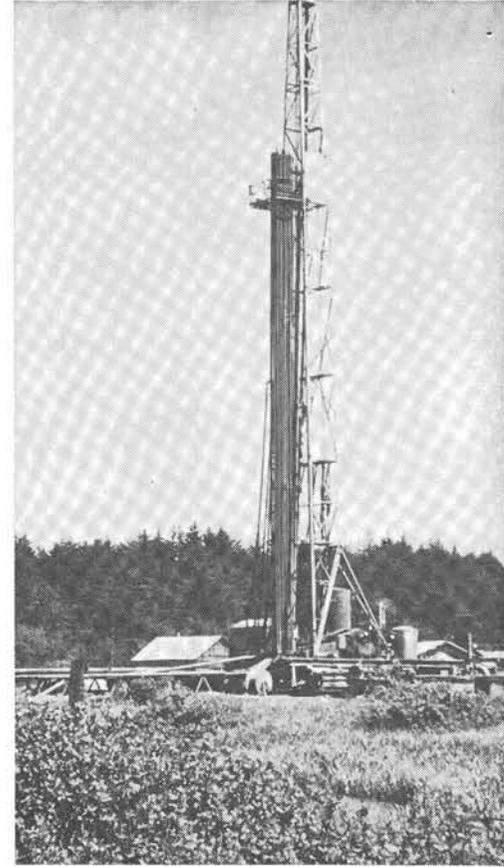
Bakersfield, Calif.

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WASHINGTON SCENES. Governor Albert D. Rosellini of Washington State (above center) watches oil and gas flowing from Sunshine Mining Company's Medina 1 at Ocean City

in August 1957. This was Washington's discovery well. A magnetometer survey (below left) being conducted in the Ocean City area. Above right is Utah Consolidated's Swanson



22-1, which found oil and gas shows at 2,100-2,300 feet and gas at 3,940 feet. Below right is Union Oil Company of California's State 3. This well was drilled in 1949 finding shows of



What are the prospects in Washington State?

Untested oil and gas possibilities are tremendous, but will yield only to those operators with know-how and the means to find it

By **F. H. Wurden**, Petroleum Consultant
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THE OCEAN CITY ANTICLINE, a seismic prospect located on the Pacific coast of Washington state, ranks as that state's main oil prospect despite 10 unsuccessful attempts in as many years to develop commercial oil and gas production. All tests drilled on the prospect reported strong shows of oil and gas. One well, Sunshine Mining Company's Medina 1 drilled in 1957, has produced more than 8,000 barrels of high gravity oil.

Most of the tests have been drilled on a quarter-mile wide sand dune strip between the Pacific ocean and the upland timbered area. Operators have been plagued by engineering difficulties and, due to a lack of information on subsurface conditions, completion and testing practices have proved inadequate. As an example of the bad luck encountered in the area, Union Oil Company, discoverers of the structure (1946), drilled five of the 10 wells, and was forced to abandon a critical deep test following a series of fishing jobs and cementing failures. The test, Union's State 3, was projected to 12,000 feet for a test of deep-lying Eocene sediments. This well encountered high pressure

gas at about 3,700 feet. After a number of unsuccessful attempts to complete, it was abandoned at 9,344 feet.

A table on Page 98 lists all wells drilled on the Ocean City prospect up to December, 1958.

In general, sediments in the Ocean City area from 1,500 feet to a total penetrated depth of 9,344 feet emit a characteristic gasoline or kerosine odor. Numerous live shows of oil and gas have been found throughout this interval. Miocene through Eocene marine sediments are present to a depth probably exceeding 20,000 feet.

GEOLOGY

Structure: Regional—The Ocean City anticline centers around Section 15—T18N-R12W, Grays Harbor County, and is located on the east flank of a deep sedimentary basin that roughly parallels the coast of Washington. Available structural data indicate that the coastal area of western Washington is strongly folded and faulted, and occasionally intruded by Tertiary igneous masses.

The Olympic Mountains form the predominant structural feature of the area with present structures along the

About the Author

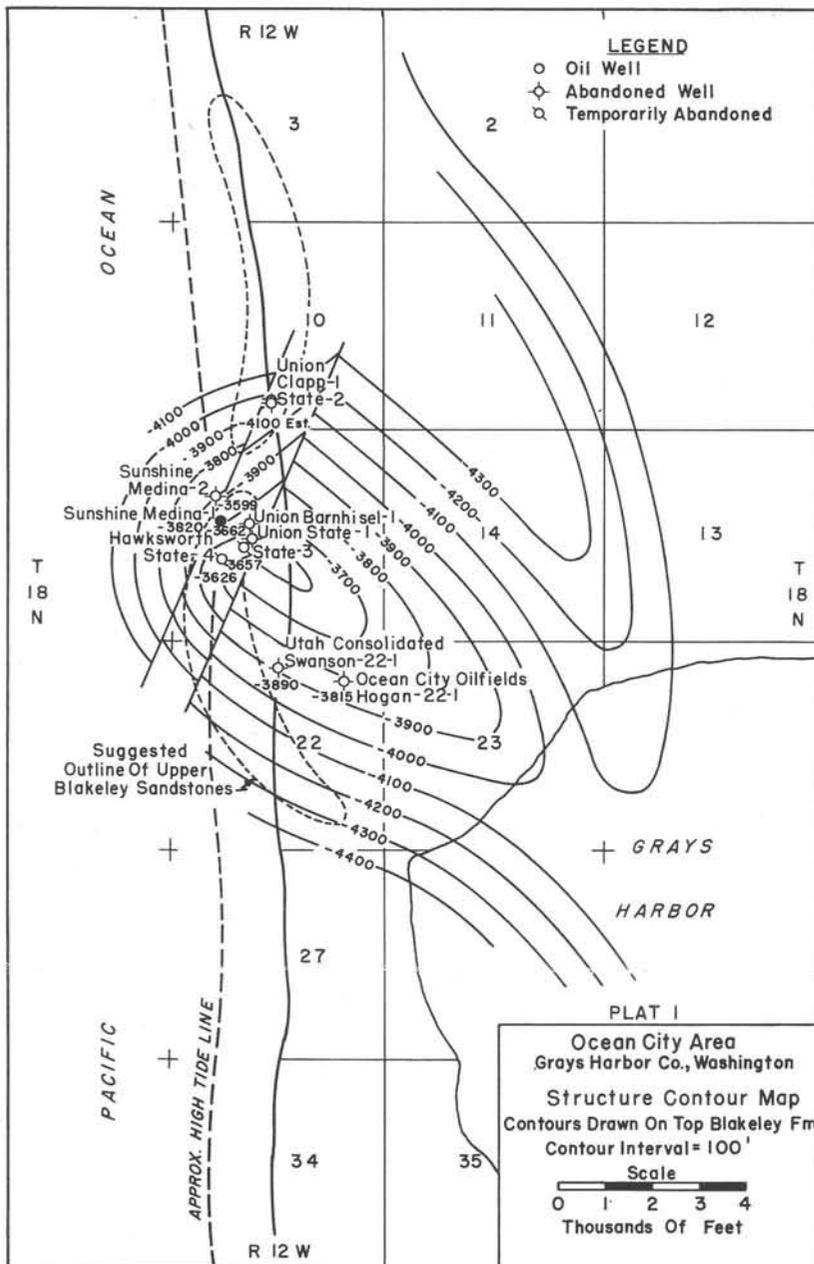
Fred H. Wurden helped organize and supervise Sunshine Mining Company's exploration program in Washington state prior to March of 1958. He is now a partner in the firm of Larsen and Wurden, petroleum consultants, in Billings, Mont. Wurden is a graduate Colorado School of Mines. Before he joined Sunshine Mining in 1956 he was employed as a geologist with Murphy Corporation in Billings.



oil and gas in the Blakely formation that touched off the oil play in Washington. Sunshine's Medina 1 is located about 600 feet north of this well, which is temporarily abandoned.



(Photographs courtesy the author and the Department of Conservation and Development, Washington State.)



Subsurface geological interpretation of the Ocean City anticline, Grays Harbor County, Washington, shows the productive area as a narrow faulted zone. Lenticular sands are indicated.

Eocene outcrops being on the surface northwest of Hoquiam (a town about 27 miles east of the prospect). The north flank of the structure is limited by a syncline trending through Sections 3, 10, 11 and 14, T18N, R12W. To the south the structure is limited by a syncline trending northwest-southeast through Sections 34 and 35, T18N, R12W. South of the township line the sediments again dip to the north as they rise up on the Duck Lake structure. Although no structural data are available west of Section 15, T18N, R12W, it is assumed that the sediments continue the trend from Eocene outcrops at Aberdeen and dip sharply to the west.

Faulting—Two faults have been found in the area on the basis of electric log correlations alone. These are shown on Plat 1 trending north-northeast through the crest of the structure. Although the trend of these faults was originally plotted on the basis of well control only, they also parallel the trend of a major fault along the west flank of Quinault Ridge. Each of the faults dips to the southeast with the southeast side downthrown. Other faults are possibly present but cannot be definitely located by well control alone.

The easternmost of these two faults cuts Union's State 1 and State 3 in the Lower Miocene Ocean City formation, resulting in a shortening of this interval in these two wells. The same fault apparently cuts out the middle sandstone member of the Astoria formation in Union's Barnhisel 1.

The westerly fault crosses the Medina 2 at about 1,500 feet, cutting out an interval equal to that between about 1,500 feet and 1,650 feet in the Medina 1.

Stratigraphy: General. Major stratigraphic units can be correlated on a lithologic basis for considerable distances in western Washington. As is often characteristic of Tertiary sediments, however, individual sandstone units are quite lenticular and difficult to predict.

Eocene sediments: For all practical purposes, the basement rocks throughout most of western Washington are composed of the middle Eocene Crescent volcanics. These rocks owe their name to exposures around Crescent Lake on the northern border of the Olympic Peninsula and are predominantly a sequence of lava flows with

coast being associated with the major tectonism involved in building these mountains. The southwest flank of the Olympics is probably a large up-thrown fault block represented by "Quinault Ridge" extending to the southwest from Quinault Lake.

Although surface sediments throughout the area are quite strongly folded, it is possible that some of this folding will die out at depth.

Local—As previously noted, the Ocean City anticline was originally mapped by the Union Oil Company and showed up on a seismic profile which the company ran along the beach. North of Section 15, T18N, R12W, this profile indicated steep

north dips; while south of Section 15, more gradual dips to the south were indicated. Several faults were also suggested by this work. On the basis of the wells that have been drilled, Union's seismic work, and gravity work conducted by Sunshine Mining Company, structure contours have been drawn and are shown on Plat 1.

These contours show a faulted anticline trending roughly northwest-southeast with the highest part of the structure located in the south half of Section 15, T18N, R12W. Although the total structural closure on the anticline is unknown at this time, it probably exceeds 400 feet. To the east the sediments rise rapidly, with

secondary amounts of pyroclastic and sedimentary rocks. In many parts of western Washington the Crescent formation is unconformably overlain by the middle and upper Eocene McIntosh and Skookumchuck formations. In the Chehalis area, the McIntosh formation is of marine origin and consists of tuffaceous siltstone and shale with minor amounts of sandstone, while the Skookumchuck formation is of brackish marine origin consisting of clean, porous and permeable sandstones with numerous coal and silt interbeds.

Marine equivalents of the upper Eocene Skookumchuck and Middle Eocene McIntosh formations undoubtedly underlie Oligocene sediments in the Ocean City area. The potential of these Eocene sediments is illustrated by a well drilled by the Ohio Oil Company, just north of Aberdeen in Section 5, T17N, R9W. This well flowed an estimated 2,500 to 3,000 barrels of hot, brackish water per day from an Eocene sandstone. Untested Eocene sediments in the Ocean City area could cause the oil industry to take notice of western Washington's oil and gas potential.

Blakeley formation: Unconformably overlying Eocene sediments, the Blakeley formation contains more than 6,000 feet of sandstone, shale, and conglomerate. A total of about 5,650 feet of these sediments were penetrated by Union's State 3. A characteristic petroleum odor permeated almost the entire unit. The shales of the Blakeley formation are typical source beds for oil and gas and are the "smell muds" found along the Pacific Coast of Washington. Numerous oil and gas seeps have been found in the formation which is equivalent in part, at least, to Weaver's Hoh formation to the north and to the Twin River formation on the northern border of the Olympic Peninsula. This formation is considered to be predominantly Oligocene in age. In the Ocean City area, the presently known sediments of the Blakeley formation can be divided into four lithologic units.

The lower-most unit, as found in the State 3, consists of a dark grey, fractured shale of unknown thickness.

Overlying this unit is about 2,550 feet of conglomerate and sandstone with minor amounts of shale. Numerous cores in the lower 900 feet of this interval had good shows of oil and



Index map of Washington State shows location of area discussed here.

gas. However, the permeabilities were extremely low and unless formation fracturing will help, it is questionable whether or not this zone will ever produce appreciable amounts of oil or gas. The zone has not been adequately tested, having had 2,665 feet of heavy mud over it when swabbing operations were discontinued in Union's State 3.

About 1,650 feet of shale with thin sandstone beds overlies the lower conglomeratic zone. Several shows of oil were found in these very thin sandstone intervals in Union's State 1.

By far the best shows of oil and gas in the Ocean City area have been found in the upper 700 to 1,000 feet of the Blakeley formation. Sediments in this unit have been described as a gouge zone, grit zone etc. Actually this interval is predominantly a very poor type of conglomerate containing up to first sized subangular pieces of hard sandstone, siltstone, and hard black shale in a matrix of soft, dark grey shale. Most of the oil and gas produced in the field has come from several tight fractured sandstones in the upper part of this interval. In the lower part of this zone, at about 4,300 feet in the State 3, a fairly good oil sand was penetrated with excellent permeabilities. This sandstone probably correlates with the sand at 4,170 feet in the Medina 2 and the sandstone interval between 4,330 and 4,450 feet in the Hogan 22-1.

Several high pressure oil and gas zones are present near the top of the Blakeley formation. The State 3, State 4, and the Medina 1 all produced oil and gas from these sandstones. Each

of these three wells produced a different gravity oil. Obviously these different crudes are coming from separate reservoirs. In the Medina 1, a part of these sandstones were cored. Analysis showed almost no permeability and very low porosity, with oil and gas apparently coming from fractures in these sandstones. The sandstone at 3,700 feet in the State 3 is considered to be the same type of reservoir. Unfortunately the electric log did not penetrate to total depth in the State 4, making it difficult to evaluate these reservoirs.

The geological environment during Blakeley time is clearly recorded by the sediments deposited. During most of this time a near-by land mass was being rapidly eroded. In early Blakeley time there was apparently a long quiet period of moderately deep marine sedimentation as shown by the lower shale unit. Near-by uplift, probably in the Olympic Mountains, resulted in a period of rapid deposition, as shown by the lower conglomerate and sandstone interval. Either the adjacent land mass subsided or was reduced to a very low outline and continuing erosion and deposition resulted in the second shale unit. Near the end of Blakeley time this land mass began rising again, resulting in periods of landslide proportion deposition. This uplift continued until a large part of western Washington, including the Ocean City area, was raised above sea level and subjected to erosion. During this time the coastline fluctuated back and forth and at times probably approximated the present coast. Although other explanations

Wells drilled on Ocean City prospect to December 1958 . . .

Operator	Well No.	Total Depth	Oil and Gas Shows
Union Oil Co.....	Barnhisel 1 (strat)	2,657'	1,140-1,573 feet, (gasoline-kerosine odors).
Union Oil Co.....	Clapp 1 (strat)	3,997'	2,000; 2,460-70 feet, (oil); 3,650-3,730 feet, (gas).
Union Oil Co.....	State 1	6,278'	3,700 feet, (gas); 3,884-3,928 feet, (gas cut mud); Perforated 3,630-3,885 feet, (swabbed 100 bbls. 37 gravity oil).
Union Oil Co.....	State 2 (strat)	3,805'	3,585 to 3,769 feet, (gasoline-kerosine odors).
Union Oil Co.....	State 3	9,344'	3,700 feet, (high pressure gas); Perforated 3,670-4,676 feet, (pumped up to 100 barrels of oil per day).
Hawksworth and Associates.....	State 4	3,771'	3,587-3,712 feet, (2 Mcf gas, 35-40 barrels 44.2 gravity oil per day).
Ocean City Oilfield and Utah Consolidated Oil...	Hogan 22-1	4,864'	4,330-4,440 feet, (oil).
Utah Consolidated.....	Swanson 22-1	4,381'	2,100-2,300 feet gas; 3,940, (gas).
Sunshine Mining Company.	Medina 1	4,130	3,952-58 feet (IP 180 barrels of oil; well has produced more than 8,000 barrels of oil).
Sunshine Mining Company.	Medina 2	5,125	3,010-35 feet and 4,160-80 feet, (oil/gas).

are possible it seems likely that the sandstones in the uppermost Blakeley are ancient beach sands or offshore bars. If so, their trend should roughly parallel the present coast line. A suggested outline of these sands is shown on Plat 1. Although present data indicates that these uppermost Blakeley sands are fracture type reservoirs, a little experience with sandstone reservoirs in general will illustrate how rapidly these sands will clean up over a very short horizontal distance.

Ocean City formation: At the end of Blakeley time the area again subsided and about 1,700 feet of marine shales in the Ocean City formation were deposited. These sediments are also permeated with a strong gasoline or kerosine odor and are undoubtedly source beds for oil and gas. In the Medina 1 at about 3,010 feet, an excellent show of oil and gas in this interval is shown by a drill stem test between 3,010 and 3,041 feet which flowed oil and gas in 50 minutes. The Ocean City formation is a "heaving shale" which requires mud in excess of 14 pounds per gallon to drill the interval.

Astoria formation: At the end of lower Miocene time the area was again uplifted and subjected to erosion. As shown by the Swanson 22-1 and the Hogan 22-1 wells, deep channels were cut in the lower Miocene sediments and filled by the middle (?) Miocene Astoria sandstone. This sandstone is predominantly a blanket type sand covering a large part of western Washington, extending southward into Oregon, and deriving its

name from outcrops along the Columbia River near Astoria, Oregon.

In the Ocean City area sedimentation continued, apparently uninterrupted into upper Miocene time, depositing about 1,000 feet of sands and shales in the upper Astoria unit.

Quinault formation: The Quinault formation consists of about 1,200 feet of sandstone of continental origin and derives its name from outcrops along the Pacific Coast near the mouth of the Quinault River, about 20 miles north of Ocean City. Logs, twigs, leaves and other organic matter are common. These sands grade upward into the present beach sands. The Quinault is Pliocene in age.

Area's oil possibilities are interesting. That oil and gas can be produced in the area is illustrated by the Sunshine Mining Company, Medina 1, which has to date produced more than 8,000 barrels of oil. Several different gravities of crude oil have been produced from the various wells in the field indicating at least four pressure oil and gas reservoirs in the upper Blakeley formation. Available information indicates that at least three of these reservoirs are tight, fractured sandstones. However, this does not eliminate the possibility of finding clean sandstone reservoirs in the immediate area.

Oil shows in the lower conglomerate zone of the Blakeley formation have not been properly tested. The future of the Ocean City field depends on this interval, untested Eocene sediments, and the upper 1,000 feet of the Blakeley formation.

If the sands in the uppermost Blakeley formation are beach sands in origin they will be long and narrow in shape and considerable care should be exercised in making new locations.

Drilling operations in this area will be expensive due to the "heaving shale" in the Ocean City formation. Mud weight in excess of 14 pounds per gallon is required to control this zone. Use of this heavy mud over a reasonable period of time probably will not damage the oil and gas reservoirs in the area.

Oil and gas to date has been produced from sandstones and not shale intervals. Even though these shales give off a strong gasoline or kerosine odor, it is very doubtful that appreciable amounts of oil or gas will ever be produced from them. In fact they are generally so soft that care should be taken during perforating so that no bullets enter a shale interval.

The use of slotted or perforated liners has resulted in considerable trouble in completing these wells. During drilling operations, oil and gas zones should be pinpointed by cores and drill stem tests. Pipe should then be cemented through these zones and perforated for production testing.

The history of the Ocean City area has been one of an endless series of troubles that have resulted in unfortunate expense to the operators, and others should profit from their experience. Western Washington has a tremendous untested oil and gas potential that will yield only to operators with the know-how and the means to find it. —The End

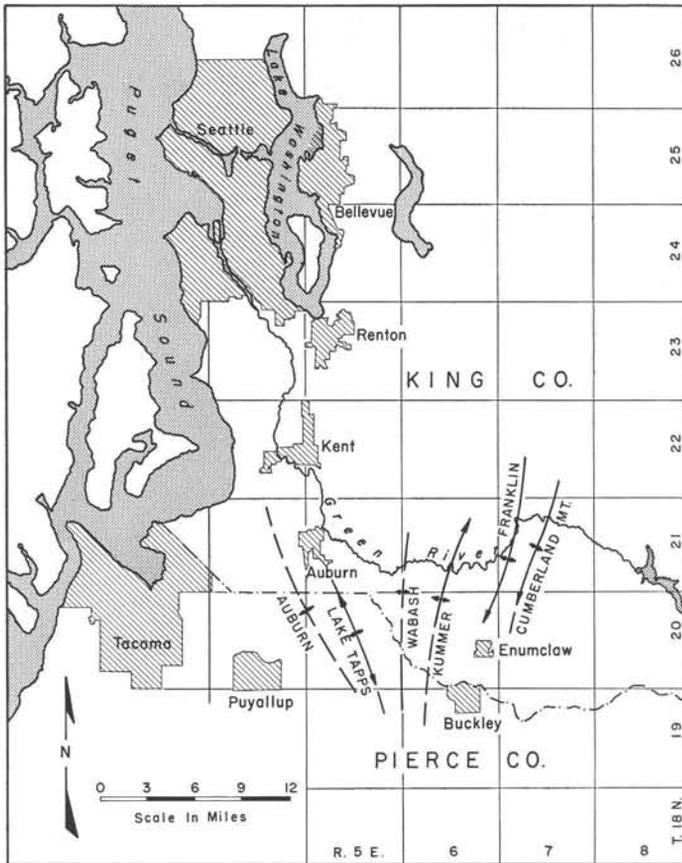


FIGURE 1—Index map of Green River district showing location of several anticlinal folds.

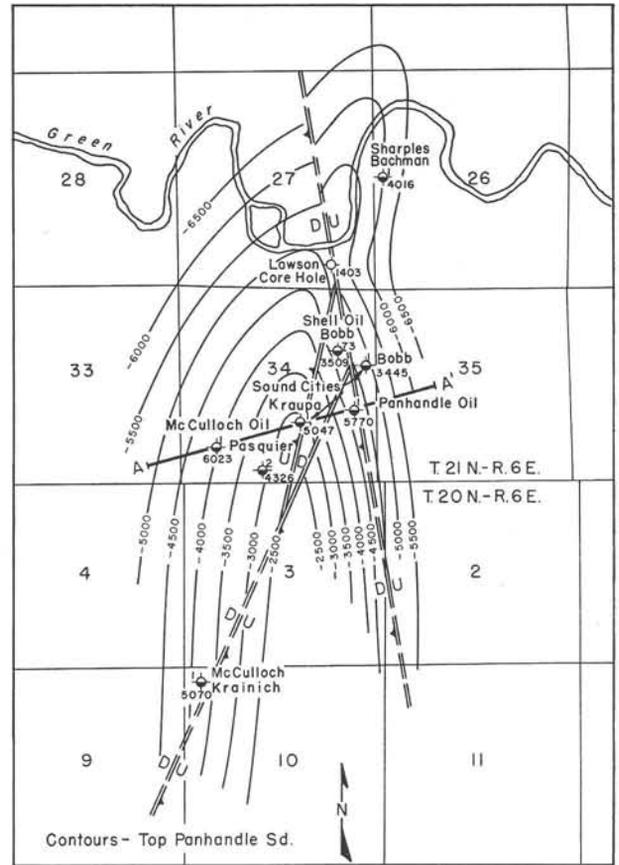


FIGURE 2—Structural contour map of northern portion of the Kummer anticline, showing indicated complex structure.

Puget Sound area has several prospective oil and gas basins

Great thicknesses of Upper Cretaceous and Tertiary sediments, large structures comparable to productive California areas

By J. Q. Anderson, Consultant
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THE GREEN RIVER district of north-west Washington State is an area of major interest to many operators. Despite many difficulties, known data

justify high promise of significant oil and gas reserves. The large population of the Puget Sound district ensures a ready market for any oil and gas found.

To date, no commercial success has been attained by any oil prospector. However, in recent years, a flurry of leasing and drilling activity was occasioned by the limited production obtained by the Sunshine Mining Company in Grays Harbor County. In the Enumclaw district of Kings County, McCulloch Oil Exploration Company of California, Incorporated, stimulated more than passing interest with three wildcat ventures in 1957 and 1958. These tests had many significant shows

of high gravity oil in a large number of thick and permeable massive sand zones.

Geological studies have proven the existence of a number of sedimentary basins. These basins contain large thicknesses of Upper Cretaceous and Tertiary rocks, both marine and non-marine.

The necessary factors requisite to the origin and entrapment of oil and gas are favorably comparable to known productive areas in California. Lack of persistent wildcatting therefore has limited success in several areas which are geologically promising. By way of comparison, wildcat well density is over 75 times greater

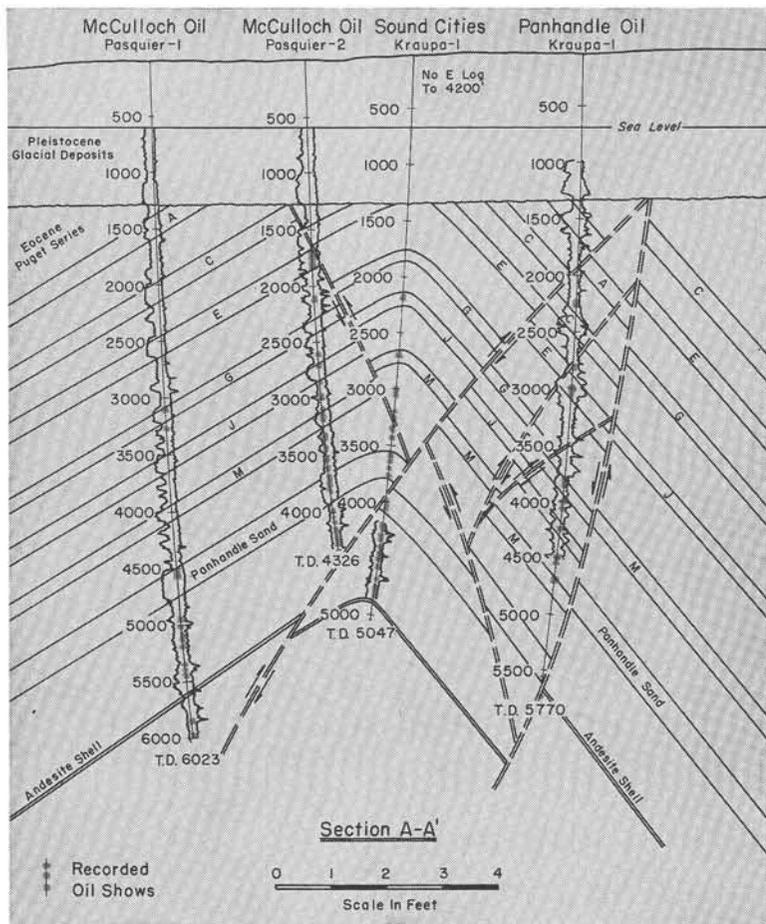


FIGURE 3—Structural cross-section, northern end of Kummer anticline.

in California oil basins than the potential basins in western Washington.

Exploration obstacles. Various methods of geological exploration in western Washington have proven to be quite frustrating. Most of the land surface is covered with a dense growth of vegetation which precludes the accurate delineation of scattered outcrops into a contiguous pattern. Most outcrops are limited to road-cuts, precipitous mountain slopes, and stream drainages. A surface geological map therefore resembles a jig-saw puzzle with most of the pieces missing. Sub-surface interpretations from such limited data are obviously quite hazardous, especially in areas where structural and stratigraphic complexities are known to exist.

The presence of Pleistocene glacial debris in many of the lower topographic areas adds to the geologist's frustration. Obviously, all pre-glacial rock sequences are obscured and the only available outcrops are

sought in the beds of streams and rivers which have incised a course beneath the glacial debris.

Many obstacles confront geophysical exploration in such areas. In many instances the drilling of seismic shot holes has been almost impossible, especially in areas of unconsolidated glacial cobbles and boulders. Frequently, the reflections obtained are seldom determinative of true subsurface structural conditions.

Gravimetric and magnetometer surveys occasionally provide subsurface clues. However, the presence of *iron-rich basalt boulders* in the glacial deposits or buried masses of volcanic rocks frequently result in false anomalies.

The foregoing impediments to detailed exploration have inhibited wild-cating in western Washington. Many of the previous tests lacked permeable reservoir rocks although good oil shows in biogenetic source beds often were found to be present. It appears that areas to be considered for future

drilling should be limited to those districts wherein the presence of closed structures, permeable reservoir rocks, and definite oil shows can be demonstrated.

Green River district promising. Of the several districts which afford high promise in western Washington, the author considers the Green River district to be prospective. This district comprises approximately 600 square miles and is roughly bounded in triangular pattern by the towns of Seattle, Tacoma and Enumclaw (Figure 1). Here again, most of the surface geology is obscured by dense vegetation and glacial deposits. However, all of the surface and subsurface data thus far obtained indicates a favorable potential for oil and gas in this area.

A series of parallel folds occurs on the easterly and westerly flanks of an anticlinorium, the axis of which has a general northward trend from the town of Enumclaw. Outcrops in the bed of the Green River have revealed this series of folds, although such features as length, possible closures, faults, and stratigraphic variations are partially obscured. Surprisingly enough, only one of these folds, known as the Black Diamond or Kummer anticline, has been drilled to date.

A sequence of arkosic quartz-feldspar sands, sandy shales, carbonaceous shales and occasional coal seams known as the Puget Series occurs in the Green River district. These sediments are upper Eocene in age and vary in thickness from 2,000 to over 10,000 feet. Most of these sediments are non-marine in origin but occasional lagoonal or brackish water mollusks have been found in thin interbeds.

In adjacent areas, marine rocks of Oligocene and Miocene age overlie the Puget Series. Such rocks may have been source beds for oil and gas which migrated into reservoir rocks of the Puget Series. Significant shows of oil and gas from the Kummer anticline tests prove the presence of migratory oil into this series. Substantial production from non-marine sediments in several oil fields in California and more recently in Alaska proves that exploration for oil in such sediments can be highly successful.

Area and flowing well. Test wells

Kummer anticline yielded oil, gas . . . core test geysered . . . Bobb well made oil

drilled on the Kummer anticline have yielded significant information in evaluating the oil and gas potential of the Green River district. In 1915, attention was first drawn to this area by the drilling of a 1,403-foot core hole on the northern plunge of the anticline. This well, known as the Lawson test, was drilled to ascertain the subsurface extension of several coal seams which were then being mined in the adjacent Black Diamond district. At total depth, the well geysered, blowing the tools out of the hole. Following abandonment, the well continued to flow saline water and discharge gas by heads as high as 75 feet or more. Today, after 44 years, gas and water still bubble from this hole.

From 1937 to 1940, drilling operations were carried on in intermittent fashion by the Sound Cities Gas & Oil Company. Their first well, "Bobb 1" (see Figure 2), was drilled to a total depth of 3,440 feet. The hole was cased with 10-inch casing and all promising sand zones were gun perforated in one operation. This resulted in the hole being flooded with water. The operators then placed a packer on the tubing at 3,200 feet and attempted to pump for production from intervals below 3,200 feet. Pumping operations yielded several hundred barrels of salt water per day along with a fair volume of gas. This gas was piped to the company's other test, "Kraupa 1" and was used for fuel to fire the boilers during drilling operations.

After pumping water and gas for over a year, the Bobb well started making considerable free oil. The operators then erected a 600-barrel tank on the property. When completed, the well was flowing oil through the tubing and was making considerable sand. The flow was turned into the tank, and when it was approximately two-thirds full of oil, the well "headed in" with such violence that the tank collapsed. The well abruptly ceased flowing after heading in. Rods, tubing, and packer were pulled and it was discovered that a groove along the side of the packer was filled with a limy mineral deposit. This indicated that the original groove permitted water entry from up the hole into the

zone below the packer during the long period of pumping. A complete water shut-off had been finally effected by the gradual deposition of lime scale in the groove. This resulted in the brief production of approximately 500 barrels of oil within a 14-hour period. High pressures had completely clogged the pump with sand thereby accounting for the abrupt cessation of production. The oil was 24 to 26 gravity.

In an attempt to ensure production, the operators then placed a charge of 200 quarts of nitroglycerine in the bottom of the hole. The charge was exploded, the casing collapsed, and all further attempts to clean out to bottom were futile.

The oil zone in the Bobb well consisted of a 20-foot sand bed which was sealed up dip by a large normal fault.

In the period from 1945 to 1957, three other wildcat tests were drilled on the Kummer anticline. All of these wells had interesting shows of oil and gas but no commercial promise. A geological review of the surface outcrops and all sub-surface data by the writer resulted in recommendations for further prospecting. All previous tests were located on the northeast flank of the structure and were presumed to be too low structurally for anticlinal closure.

Recent tests had good shows. In

About the Author



J. Q. Anderson has been active as a consulting geologist since 1949. He received his B.A. in geology from the University of Southern California at Los Angeles in 1937 and, following graduate work, joined Union Oil Company of California. He did field geological work in California and the Rocky Mountains for Union, and has since worked in Washington State, among other areas, for other companies. He is also experienced in petroleum engineering work.

1957 and 1958, McCulloch Oil Exploration Company of California, Incorporated, drilled three tests on this structure. Core analyses from these wells showed permeabilities ranging from 50 to 3,500 millidarcys and porosities as high as 35 percent. Most of the massive sand zones penetrated had oil and gas shows. These shows were manifested by a bright blue fluorescence of the ditch cuttings under ultra-violet light. Some of the cores had a light tan oil staining and occasionally bled free oil. A total of 16 sand zones were correlated in these wells. The combined thickness of the sands averages 1,800 feet. The oil shows in these sand zones are depicted in the cross section, Figure 3.

Electrical logs of the three wells indicated all sand zones to be wet with salt water. Several drill stem tests confirmed this fact, yielding nothing but a small volume of mud, salt water, and a slight oil scum. Oil samples were too meager for analysis but an approximation of 30 gravity or better would be reasonable.

At the present time, there is no proof that structural closure exists on the Kummer anticline (see Figure 2). All of the wells thus far drilled appear to be located on the north plunge. There is ample evidence that fault traps exist. However, with the exception of the Bobb 1 well, the fault blocks on the north plunge have proven to be barren.

Other structures untested. It should be emphasized again that the Kummer anticline is but one of a series of folds in the Green River district that has been only partially tested to date. Limited data indicates that these folds have lengths of from 6 to 10 miles and average widths of from 2 to 3 miles. The hope for commercial success in any future prospecting in this area is based on the following conclusions:

1. It is likely that millions of barrels of oil have traveled through the many porous sand zones of the Puget Series. Entrapment of portions of this oil in commer-

cial quantities is yet to be proven.

2. The sand zones of the Puget Series have varying permeabilities and porosities, most of which are sufficient to contain vast quantities of oil and gas.
3. Marine sediments are present in some areas of the Green River district and it is presumed that they generated some of the oil which has migrated into the Puget Series. It is probable that many of the structures west of the Kummer anticline also have substantial interfingerings of marine sediments.
4. The orogenic events in the structural history of the Green River district were of sufficient magni-

tude to assure a high degree of folding and faulting. Such events would favor the probability of anticlinal closure on several of the structures in this area.

Core hole drilling needed. Although the foregoing conclusions suggest a favorable potential for commercial oil and gas in the Green River district, many problems remain to be solved by the wildcatter. The obstacles to detailed exploration, as listed previously, would entail the expenditure of considerable capital. The most desirable objective would be to obtain good evidence of anticlinal closure before drilling to any great depth. This could be accomplished best with a vigorous core drill program.

There are several areas in the Green River district where the thickness of the Pleistocene and Recent deposits is less than 500 feet. A core hole program in such areas to depths of 1,000 to 1,500 feet would certainly provide key answers for future wildcatting.

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